Step Time Adjustment During Simple And Choice Stepping Task

By

Jaber Nassir Alshaye

Submitted to the faculty of the University Graduate School
in partial fulfillment of the requirements
for the degree
Master of Science in Kinesiology
in the Department of Kinesiology
Indiana University
April, 2017

Accepted by the Graduate Faculty, Indiana University, in partial fulfillment of the requirements for the degree of Master of Science in Kinesiology.

John B. Shea, Ph.D., Chairperson

David M. Koceja, Ph.D.

Hannah J. Block, Ph.D.

April, 25 2017

ACKNOWLEDGMENTS

First and foremost, I thank God for providing me with strength and persistence through my life.

I would like to thank a number of people who supported me, helped me, invested and believed in me. My father and my mother for their never-ending and unconditional love, support, trust, believes, prayers, and encouragement. Without them I would never be where I am now. I also want to thank my family and friends for their constant support and prayers.

I am also grateful to have Dr. John Shea as my supervisor. He has been a great supervisor since I started my degree at Indiana University. His feedback, critiques, and help have transformed me into a better researcher. The support and the time he provided me with have contributed in significant ways to the expansion of my knowledge in and out the field of Motor Learning and Control. I owe a debt of gratitude to him.

I want to express my appreciation to both Dr. David Koceja and Dr. Hannah Block for playing an important role on maximizing my knowledge of the field. I also want to thank them for agreeing to be in my Thesis Committee and providing me with valuable advice.

I want to send special thanks to my friend and colleague Ruopeng Sun for his enormous help in the beginning of my research.

I am also grateful to my employer, Majma’ah University, for providing me with the opportunity to pursue my dream of continuing my academic studies.

Finally, to Indiana University and faculty, staff, and fellow students in the Department of Kinesiology and School of Public Health thank you very much for making me feel like I have never left my country.

ABSTRACT

Jaber Nassir Alshaye

Step Time Adjustment During Simple And Choice Stepping Task

Introduction. Information regarding stepping time plays an important role in understanding normal and abnormal human gait. Adjusting the time for stepping during gait is a common strategy individual may demonstrate to maintain gait balance. Therefore, we analyzed the stepping time among eight healthy young individuals during both a simple reaction time task (SRT) and a choice reaction time task (CRT). **Purpose.** The objective of this study is to investigate if SRT and CRT have different effects on Step Time. A secondary aim of this study is to discuss the importance of using the information regarding step time to improve gait training designed for those with gait impairments in physical rehabilitation programs. **Methods.** Eight healthy young subjects (18-24 years old) participated in this study. All of the participants (four females, four males) were right-leg dominant. Participants were instructed to stand upright and barefoot on a force platform with their feet 25 cm apart. Throughout the experiment, a tape was used to ensure a consistent distance between participants' feet while standing. Subjects looked straight ahead during the entire trial, with eyes directed toward a target (+) presented on a screen 4 m ahead at eye level. A visual stimulus was presented and remained on the screen for 10 seconds after the (+) sign appeared, allowing subjects to get ready to respond with the appropriate foot and the exact number of steps. We used repeated measures *t*-test in SPSS to compare the means of ST during SRT and CRT tasks **Results.** There was no statistically significant difference in ST for SRT task (M=1207.8, SD=73.6) and CRT task (M=1234.1, SD=67.1) (t (7) = - 1.5, p = 0.17) **Conclusion.** Our results suggest that CRT task has no strong impact on ST. However, the small number of participants must be considered a main factor, which led to this result.

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION

1.1 Background

For individuals with gait impairments, falling during walking, which often leads to injuries and decreases in mobility is a common problem (20, 28, 29). Age-related changes in the neuromuscular system have been shown to be responsible for the higher rates of falls among the elderly (10, 26). Ambulation, walking in particular, is an essential part in maintaining independence and quality of life among healthy and non-healthy elderly individuals (35, 37). Studies show that elderly fallers had a smaller step length (distance between the toe of two subsequent feet) than elderly non-fallers. Also, old individuals with high risk of falling secondary to their neuromuscular gait impairment demonstrated higher spatiotemporal variability during gait initiation (36, 45). In fact, approximately one-third of adults over 65 showed a tendency to fall during locomotion (40). Over the last two decades, gait variability has been measured to improve the understanding of dynamic balance (2, 30). Many studies have considered balance perturbations to investigate how people respond to challenges made to their gait stability (11, 24, 25). Information regarding human gait cycle plays an important role in understanding normal and abnormal individuals' gait. In order to maintain their dynamic balance and in preparation to stop, healthy as well as non-healthy individuals may use various strategies during walking.

In gait analysis, reaction time (RT) is known to be the time between a stimulus and a movement or a step executed by an individual. The two main types of RT are simple reaction time (SRT), where participants respond to a single stimulus, and choice reaction time (CRT), where they must have a specific response in accordance to the type of given stimulus (4). Many studies have divided gait initiation into five main stages: the reaction time, the release phase, the unloading phase, the single support phase, and finally, the double support phase (5, 23, 27). Stepping on the ground, an individual will initiate a force vector in downward-backward direction. As a reaction to the produced force, the ground produces another force in the opposite direction (upward and forward). This is called the ground reaction force (GRF), which is measured by a force plate (41). Information about GRF is crucial to measure step time. It is generally believed that self-modification of gait triggers changes in gait pattern (6, 9). Gait has been shown to have different effect on gait stability based on the type of gait challenge introduced to an individual. Some studies have proposed that a faster gait is the main strategy individuals might use to improve their gait stability (1). While walking, individuals may intentionally alter their stepping pattern to enhance their stability (3). However, in order to maintain their gait and in preparation to stop, both healthy and non-healthy individuals may use various strategies during the five main stages of gait. It is of great importance for both clinical and science purposes to understand the various shapes that voluntary walking individuals demonstrate to maintain their safety.

1.2 Statement of the Problem

Information regarding human gait cycle plays an important role in understanding normal and abnormal gait of individuals. In order to maintain their gait and in preparation to stop, healthy as well as non-healthy individuals may use various strategies during the five main stages of gait. Therefore, knowledge of these strategies is of great importance in physical and functional rehabilitation since they reflect neuromuscular gait control. Adjusting step time during gait is a common strategy individuals may demonstrate to maintain a successful step task. However, little is documented throughout existing research regarding the step time during different stepping tasks.

1.3 Purpose of the Study

The purpose of this study was to investigate if there is any effect of the type of reaction time task on step time. A secondary goal was to understand how individuals plan their steps in two different stepping conditions through modification of their step time. Another secondary goal for this study was to discuss the importance of using the information regarding step time to improve gait training designed for those with gait impairments in physical rehabilitation programs.

1.4 Delimitations

A total of eight healthy college-age participants, four males and four females aged from 18-24 years old, from Bloomington, Indiana were recruited for this study. The study was conducted at Indiana University's Neuromotor control and gait analysis laboratory at the School Of Public Health. Step time was the dependent variable that was examined in this study. Several independent variables were examined in this study including stepping task (simple or choice), and the number of steps taken (one, two or three). All participants were asked to perform two stepping tasks (simple and choice reaction time tasks). We used paired sample t-test to analyze our data.

1.5 Assumptions

This study was conducted under the following assumptions:

1. The participants were representative of healthy young male and female adults of average college age with no history of any physical or neuromuscular problems.

2. The participants did not anticipate any given stimulus and did not react in advance.
3. The participants were motivated to perform the stepping task at their best condition during each data collection session.
4. To provide adequate practice for each participant to reach the sufficient level of understanding of the task to perform and without any learning effect, the five trials of each condition in simple reaction task and the ten trials in choice reaction task were adequate.

1.6 Hypotheses

This study was designed to investigate the following null hypotheses:

Hypothesis 1: There were no significant differences between Simple Reaction Time (SRT) task and Choice Reaction Time (CRT) task as a main effect on Step Time (ST).

Hypothesis 2: There were no significant differences among the number of steps as a main effect on step time (ST).

1.7 Definitions of Terms

<u>*Reaction Time (RT):*</u> the time between the given stimulus and the step executed by the participant.

<u>*Simple Reaction Time (SRT) task:*</u> this refers to a stepping task in which participants were informed about the number of steps they had to perform and the exact foot they had to use to initiate the step before each testing block. This SRT task varies from one step to three steps.

<u>*Choice Reaction Time (CRT) task*</u>*:* this refers to a stepping task in which participants had to perform a specific task in accordance to the type of given stimulus (six different visual cues generated by a computer to give information regarding the number of steps and the type of foot). This CRT varies from one step to three steps.

Step Time (ST): this refers to the time from swing foot toe off (SWTO) until the initial contact of the same foot to the ground (SWIC).

Swing Foot Toe Off (SWTO): this refers to the moment the toes of the foot (or the foot) used to perform the step(s) leave the ground.

Swing Foot Initial Contact (SWIC): this refers to the moment the foot (or part of the foot) used to perform the step(s) come into contact with the ground.

CHAPTER TWO

LITERATURE REVIEW

2.1 Reaction Time

Reaction time (RT) has always been an essential part to the investigation of human behavior studies (44). Reaction time is known to be the time between a stimulus and a movement or a step executed by an individual. As stated in chapter one, the two main types of RT are simple reaction time (SRT), where participants respond to a single stimulus, and choice reaction time (CRT), where they must have a specific response in accordance to the type of given stimulus (4). It has been proposed that age, physical status, exercise, and stress have a remarkable influence on RT (44). CRT has been measured alongside various sensorimotor and balance measures and considered a strong predictor of falls among elderly. Late step time has been a significant factor to identify individuals with high risk of falling from those from non-fallers (22, 33).

2.2 Gait and Gait Parameters

The walking speed (the product of cadence and stride length (m/s)) of both young and elderly has been postulated to have a significant influence on the variability of the spatial–temporal gait parameters (e.g swing phase duration) (15, 16). The walking speed is an important factor to be considered when measuring gait parameters. The effect of walking speed on gait among individuals with different neuromuscular system limitations has always been controversial in research. Various studies have showed that aging and impairment of neuromuscular system affect gait parameters. For instance, walking speed becomes slower and step lengths are shorter (18). It is believed that self-modification of step time triggers changes in gait pattern (6, 9, 43). However, slower stepping, in particular, leads to greater gait variability especially among elderly with age-related neuromuscular impairment and reduced muscular strength (15, 16). Moreover, self-modification of step time has shown to affect gait sub-phases (12).

Also, a redistribution of the mid stance phase towards the terminal stance phase when individuals increase their walking speed has been proposed in different studies. As healthy individuals increase their walking speed, their stride length (distance between the toe of two subsequent initial contact of the same foot) increases too (38). Consequently, they spend more time in leg progression during the swing phase while they reduce the stance phase duration (42). In addition, their double support phase decreases with the increase in walking speed (38, 42). The reduction of walking speed has been shown to be a strategy of choice that individuals demonstrate to cope with an increased probability of falling (9, 16). Slower walking speeds, also, help in improving local stability (6, 9, 15). However, slower walking speeds have also been proposed to be associated with increased gait variability (9, 15), which may indicate increased gait instability (13, 15, 16, 31, 32). The short step length that is associated with neuromuscular impairment and/or aging would decrease the risk of falling that occurs due to gait instability. On the other hand, the slower walking speed would have the opposite effect on gait stability. In some gait instability conditions, such as adaptation to slips, modifying step length by taking short steps seems to be the preferred strategy for individuals in comparison to increasing walking speed (1). However, it is not clear whether there is a potential for certain levels of cognitive load that could affect individuals' adaptation to the challenges introduced to their gait (8).

When it comes to individuals' response to balance perturbation, a combination of reduced step length and increased step frequency (number of steps/min) and step width (the medio-lateral distance between both heels at the moment of heel contact) appears to be the strategy of choice that individuals may demonstrate. Walking speed did not change in response to the perturbations. This could be attributed to the need to increase the stability in mediolateral and backward directions, which leads to a decrease in the risk of falls in these directions. A study measuring the effect of mediolateral balance perturbations on step length, step frequency, and step width proposed that subjects did not change their step time with increasing perturbation intensity. Instead, they made shorter, faster, and wider steps with increasing perturbation intensity (11).

Analyzing and understanding human gait cycle is an essential portion of biomechanics. Mechanical analysis of human gait is crucial to build a successful treatment program for patients with gait impairments. Spatiotemporal gait parameters help in evaluating and describing gait performance (13) since they can be severely affected by impairments in musculoskeletal or neurological systems (19). Spatiotemporal gait parameters play an important role in distinguishing between healthy individuals and those with different pathological gait (7, 34). These parameters help, also, in discriminating between fallers and non-fallers. Studies showed that both swing phase and stance phase affected gait stability (14). Additionally, gait cycle and temporal gait parameters, step length and step frequency in particular have been believed to depend on walking speed as different gait responses to walking speed have been observed in healthy and non-healthy individuals (17).

2.3 Summary

In conclusion, the changes in gait phase durations seem to be interpreted to some extent by biomechanical considerations. Furthermore, it is of great importance to know the different influences that a modification of step time has on gait phases, sub-phases, and stability. Therefore, when measuring gait parameters, we should take into account its effect on gait cycle and gait stability as well. Information regarding adjustments of walking speed, step length, and step frequency that both healthy and non-healthy individuals may demonstrate help in modifying gait training task used in physical rehabilitation clinics. A comprehensive mechanical analysis of gait parameters needs a well-defined protocol to detect gait phases' duration and their responses to changes in walking speed.

CHAPTER THREE

METHODOLOGY

3.1 Participants.

Eight healthy young subjects (18-24 years old) participated in this study (Table.1). All of the participants (four females, four males) were right-leg dominant according to self-reporting. Participants were recruited from fitness and motor learning courses at the School of Public Health. Also, none of the participants had a history of any physical or neuromuscular problems. All participants were given informed consent prior to participation in the study. The Institutional Review Board of Indiana University approved the study.

3.2 Equipment.

Eight Qualisys motion tracking system cameras (Qualisys AB, Sweden) and two force plates were used to gather position data from 12 reflective markers, which were applied on each participant's lower limbs and ankles, and to make sure participants maintained their standing balance condition. A pressure mat on top of the first force plate was used to monitor the balance conditions prior to beginning a step. Also, an HD screen was used to provide participants with the exact instruction regarding stepping and walking tasks of the two testing phases. Connected to the second force plate, a walking platform extended from the force plates and allowed subjects to take several steps throughout the experiment.

3.3 Experimental design.

This study was a laboratory experiment based quantitative study aimed to build models for analyzing gait initiation parameters. Before testing, participants completed both a medical history questionnaire and an informed consent form. They were asked to wear shorts in order to expose their lower limbs and have the anatomical markers attached to their body. There were

12 reflective markers applied on each participant. The 12 anatomical markers that were applied on each participant were: the 1st metatarsal head, the 5th metatarsal head, the lateral malleolus, and the heel of both feet, the right and the left anterior superior iliac spines (ASIS) and the right and the left posterior superior iliac spines (PSIS). All participants performed two tasks of step and walk: simple reaction time task (SRT) and choice reaction time task (CRT). Participants were instructed to stand upright and barefoot on a force platform with their feet 25 cm apart. Throughout the experiment a tape was used to ensure a consistent distance between participants' feet while standing. Subjects looked straight ahead during the entire trial, with eyes directed toward a target (+) presented on a screen 4 meters ahead at eye level (Fig.1). A visual stimulus was presented and remained on the screen for 10 seconds after the (+) sign appeared, allowing subjects to get ready to respond with the appropriate foot and the exact number of steps. This visual stimulus had 6 white squares equally divided on each side suggesting the number of steps participants had to perform (1, 2, or 3). A white square would become red, which means that the participant had to land on that square (e.g. when the right second square (LR) becomes red, it means that the participant must take 2 steps initiating the steps with the left foot in order to land on the exact square with right foot). A total of 120 trials were collected from each participant (60 trials of SRT phase and 60 trials of CRT phase). During the SRT phase, the participants performed 6 blocks of 10 trials. These were: Block 1 (L) in which the participants had to initiate one step with the left foot and land with the same foot; Block 2 (RL) in which the participants had to take two steps initiating the step with the right foot, but landing with the left foot; Block 3 (LRL) in which the participants had to take three steps initiating and landing with the same left foot; Block 4 (R) in which the participants had to initiate one step with the right foot and land with the same foot; Block 5 (LR) in which

the participants had to take two steps initiating the step with the left foot, but finally land with the right foot; Block 6 (RLR) in which the participants had to take three steps initiating and landing with the same right foot. Each of the 6 blocks was preceded by 5 practice trials to ensure participants' familiarity with the task. These practice trials were followed by the first block of 10 test trials to record the data. During the CRT phase, it was explained to the participants that in each trial the visual stimulus was equally likely to signal any of the six conditions and that the participants had to decide which foot they must use to start the task with and the number of steps required to complete the task. The participants were given 5 minute rest periods during which they were asked to sit after every 2 blocks during SRT phase, and after every 20 trials during the CRT phase.

3.4 Data Collection and Cleaning.

The motion tracking data was sampled at 100 Hz. Using a customized MATLAB (MathWorks.Inc.) program with Psychtoolbox, the visual stimulus was delivered and synced with the motion tracking system. A Tekscan HR MAT Pressure Mat (Tekscan Inc.) was placed on the first force plate (AMTI). This pressure mat allowed us to monitor the weight distribution under the feet and ensure that with no more than 51% of weight on either foot before generate any stimulation (4). All ground reaction forces (GRFs) and moments will be collected through two AMTI force plates (OR-6-7000, Advanced Mechanical Technology.Inc, MA, USA) at 1000 Hz (39). Step time is identified as the time from swing foot toe off (SWTO) until the initial contact of the same foot to the ground (SWIC). All the key time points were calculated through a customized code written in Matlab. The Qualisys Motion Capture system collected all reflective markers' data and force plate data and transported them into Qualisys. A Matlab file that contained all the kinetic and kinematic data would be generated to allow access to the raw data for each subject.

3.5 Data Analysis

To obtain the sufficient comparison of the means of the step time between the subjects during SRT and CRT, a paired sample (repeated measures) t-test was used. Since each subject was measured on two occasions on the same dependent variable, this repeated measures design ensures the sufficient comparison of the means within subjects on the same dependent variable (step time). The standard deviation was calculated to determine the scores variation around the mean. A priori Alpha level was set at $p < .05$ for all analyses.

CHAPTER FOUR

RESULTS

Eight healthy young subjects (18-24 years old) participated in this study. All of the participants completed the required 120 trials and had their ST calculated. There were 960 trials measured in this study. A paired-samples (repeated measures) *t*-test was conducted to compare the subjects' ST in SRT task with that in CRT task. There was no statistically significant difference in ST for SRT task (M=1207.8, SD=73.6) and CRT task (M=1234.1, SD=67.1) (t (7) = - 1.5, p = 0.17). However, the ST during CRT task was slower than that during SRT task by %2.2. Mean, Standard Deviation, t-value, and p-value are summarized in Table.2.

CHAPTER FIVE

DISCUSSION

The aim of this study was to investigate if Simple Reaction Time (SRT) task and Choice Reaction Time (CRT) task have different effects on Step Time (ST). A secondary aim of this study was to discuss the importance of using the information regarding step time to improve gait training designed for those with gait impairments in physical rehabilitation programs. A paired-samples (repeated measures) *t*-test was conducted to compare the subjects' ST in SRT task with that in CRT task. Our findings showed that there was no statistically significant difference in ST for SRT task (M=1207.8, SD=73.6) and CRT task (M=1234.1, SD=67.1) (t (7) = - 1.5, p = 0.17). However, the ST during CRT task was slower than that during SRT task by %2.1. The delay in ST during CRT task in comparison to SRT task can be interpreted as if subjects needed more time to either select the appropriate response, and/or execute the steps.

Despite the fact that there was no statistically significant difference in ST between SRT and CRT tasks, this delay is, to some extent, similar to the findings of some studies that suggested that step times have a significant influence on gait phases and sub-phases (12, 15, 16). It also provides compatible findings to some studies which concluded that walking speed changes and step time and other variables are not the same, and that the self-modification of individual stepping should be considered when analyzing gait parameters (6, 9). However, since we did not exclude the trails when subjects did not initiate their stepping task within 1000 ms, a delay in taking the first step could be the reason for the other 6 participants to not show any significant effect of their CRT trails on their ST. We encouraged the participants to respond immediately after the visual stimulus appeared; therefore, speeding up can be a strategy of some of them to compensate for their delay in initiating the first step.

Ambulation, walking in particular, is an essential part of maintaining independence and quality of life among healthy and non-healthy elderly people (35, 37). Studies showed that elderly fallers had a smaller step length (distance between the toe of two subsequent feet) than elderly non-fallers. Also, elderly with a high risk of falling secondary to their neuromuscular gait impairment demonstrated higher step variability during gait initiation (36, 45). In fact, approximately one-third of adults over 65 showed a tendency to fall during locomotion (40).

5.2 Significance Of The Study

The importance of using the information regarding step time to improve gait training designed for those with gait impairments in physical rehabilitation programs emerge from the fact that individuals have their own stepping strategy, movement limits, and functional challenges. An example of specific training program, which has been applied in physical rehabilitation is Multi Targets Stepping Training, which is designed to help patients with gait limitations to minimize risk of falling and maintain safe gait activities (Fig.2). Individualized functional training program based on step time, in particular, and other gait parameters, in general, can maximize the potential to ameliorate independent walking of individuals with various gait impairments. For individuals with gait impairments, falling during walking is a common problem, which often leads to injuries and decreases in mobility (20, 28, 29). Age-related changes in the neuromuscular system have been shown to be responsible for the higher rates of falls among the elderly (10, 26). Evidence about the stepping time can be utilized to prove the impact, if any, of step time adjustment on human ambulation. We believe that by understanding the effect of voluntary modification of step time on gait and its stability we can improve gait training designed for those with gait impairments in physical rehabilitation programs.

5.3 Limitations And Future Directions

This study was limited to small population (N=8) and to short gait task (three steps). Also, it was focused on only one gait parameter, which was Step Time (ST). Additionally, the only group we examined was healthy young individuals. We may consider applying more than three steps on a wider age population and a larger sample in future research. This will allow analyzing the effect of the modification of various walking parameters (step time, frequency, length, width, and walking speed) on gait and its stability. In addition, it will help in better comprehension of individuals' voluntary adjustment of their gait parameters; consequently, therapists can have greater accuracy when they modify gait and balance training in accordance to their patients'/clients' current functional ability. Also, a comprehensive mechanical analysis of gait parameters needs a well-defined protocol to detect gait phase durations and their responses to changes in gait parameters.

REFERENCE

1. Bhatt T, Wening JD, Pai YC. Adaptive control of gait stability in reducing slip-related backward loss of balance. *Exp Brain Res*. 2006;170(1):61-73.

2. Brach JS, Studenski S, Perera S, VanSwearingen JM, Newman AB. Stance time and step width variability have unique contributing impairments in older persons. *Gait Posture*. 2008;27(3):431-9.

3. Cham R, Redfern MS. Changes in gait when anticipating slippery floors. *Gait Posture*. 2002;15(2):159-71.

4. Cohen, R. G., Nutt, J. G., & Horak, F. B. (2011). Errors in postural preparation lead to increased choice reaction times for step initiation in older adults. J Gerontol A Biol Sci Med Sci, 66(6), 705-713. doi: 10.1093/gerona/glr054

5. Dalton, E., et al., Simple change in initial standing position enhances the initiation of gait. Medicine and science in sports and exercise, 2011. 43(12): p. 2352.

6. Dingwell JB, Marin LC. Kinematic variability and local dynamic stability of upper body motions when walking at different speeds. *J Biomech*. 2006;39(3):444-52.

7. Elbaz A, Mor A, Segal G, Debi R, Shazar N, Herman A. Novel classification of knee osteoarthritis severity based on spatiotemporal gait analysis. *Osteoarthritis Cartilage*. 2014;22(3):457-63.

8. Espy DD, Yang F, Bhatt T, Pai YC. Independent influence of gait speed and step length on stability and fall risk. *Gait Posture* **32**: 378–382, 2010.

9. England SA, Granata KP. The influence of gait speed on local dynamic stability of walking. *Gait Posture*. 2007;25(2):172-8.

10. Goldberg EJ, Neptune RR. Compensatory strategies during normal walking in response to muscle weakness and increased hip joint stiffness. *Gait Posture*. 2007;25(3):360-7.

11. Hak L, Houdijk H, Steenbrink F et al. Speeding up or slowing down?: Gait adaptations to preserve gait stability in response to balance perturbations. *Gait Posture*. 2012;36(2):260-

12. Hebenstreit F, Leibold A, Krinner S, Welsch G, Lochmann M, Eskofier BM. Effect of walking speed on gait sub phase durations. *Hum Mov Sci*. 2015;43:118-24.

13. Hollman JH, Kovash FM, Kubik JJ, Linbo RA. Age-related differences in spatiotemporal markers of gait stability during dual task walking. *Gait Posture*. 2007;26(1):113-9.

14. Ihlen EA, Sletvold O, Goihl T, Wik PB, Vereijken B, Helbostad J. Older adults have unstable gait kinematics during weight transfer. *J Biomech*. 2012;45(9):1559-65.

15. Kang HG, Dingwell JB. Separating the effects of age and walking speed on gait variability. *Gait Posture*. 2008;27(4):572-7.

16. Kang HG, Dingwell JB. Effects of walking speed, strength and range of motion on gait stability in healthy older adults. *J Biomech*. 2008;41(14):2899-905.

17. Kiss RM. Effect of walking speed and severity of hip osteoarthritis on gait variability. *J Electromyogr Kinesiol*. 2010;20(6):1044-51.

18. Laufer Y. Effect of age on characteristics of forward and backward gait at preferred and accelerated walking speed. *J Gerontol A Biol Sci Med Sci*. 2005;60(5):627-32.

19. Leardini A, O'Connor JJ, Giannini S. Biomechanics of the natural, arthritic, and replaced human ankle joint. *J Foot Ankle Res*. 2014;7(1):8.

20. Li F, Fisher KJ, Harmer P, McAuley E, Wilson NL. Fear of falling in elderly persons: association with falls, functional ability, and quality of life. *J Gerontol B Psychol Sci Soc Sci*. 2003;58(5):P283-90.

21. Liu, Y., Lu, K., Yan, S., Sun, M., Lester, D. K., & Zhang, K. (2014). Gait phase varies over velocities. *Gait Posture*, *39*(2), 756-760. doi:10.1016/j.gaitpost.2013.10.009

22. Lord, S.R. and R.C. Fitzpatrick, *Choice stepping reaction time: A composite measure of falls risk in older people*. Journals of Gerontology Series a-Biological Sciences and Medical Sciences, 2001. **56**(10): p. M627-M632.

23. MacKinnon, C.D., et al., Preparation of anticipatory postural adjustments prior to stepping. Journal of neurophysiology, 2007. 97(6): p. 4368-4379.

24. McAndrew PM, Dingwell JB, Wilken JM. Walking variability during continuous pseudo-random oscillations of the support surface and visual field. *J Biomech*. 2010;43(8):14705.

25. McAndrew PM, Wilken JM, Dingwell JB. Dynamic stability of human walking in visually and mechanically destabilizing environments. *J Biomech*. 2011;44(4):644-9.

26. McGibbon CA, Krebs DE. Age-related changes in lower trunk coordination and energy transfer during gait. *J Neurophysiol*. 2001;85(5):1923-31.

27. Mickelborough, J., et al., Muscle activity during gait initiation in normal elderly people. Gait Posture, 2004. 19(1): p. 50-7.

28. Miller WC, Deathe AB, Speechley M, Koval J. The influence of falling, fear of falling, and balance confidence on prosthetic mobility and social activity among individuals with a lower extremity amputation. *Arch Phys Med Rehabil*. 2001;82(9):1238-44.

29. Miller WC, Speechley M, Deathe B. The prevalence and risk factors of falling and fear of falling among lower extremity amputees. *Arch Phys Med Rehabil*. 2001;82(8):1031-7.

30. O'Connor SM, Kuo AD. Direction-dependent control of balance during walking and standing. *J Neurophysiol*. 2009;102(3):1411-9.

31. Owings TM, Grabiner MD. Step width variability, but not step length variability or step time variability, discriminates gait of healthy young and older adults during treadmill locomotion. *J Biomech*. 2004;37(6):935-8.

32. Owings TM, Grabiner MD. Variability of step kinematics in young and older adults. *Gait Posture*. 2004;20(1):26-9.

33. Pijnappels, M., et al., *The association between choice stepping reaction time and falls in older adults-a path analysis model.* Age and Ageing, 2010. **39**(1): p. 99-104.

34. Pradhan C, Wuehr M, Akrami F et al. Automated classification of neurological disorders of gait using spatio-temporal gait parameters. *J Electromyogr Kinesiol*. 2015;25(2):413-22.

35. Rejeski WJ, Mihalko SL. Physical activity and quality of life in older adults. *J Gerontol A Biol Sci Med Sci*. 2001;56 Spec No 2:23-35.

36. Roemmich RT, Nocera JR, Vallabhajosula S et al. Spatiotemporal variability during gait initiation in Parkinson's disease. *Gait Posture*. 2012;36(3):340-3.

37. Shumway-Cook A, Patla AE, Stewart A, Ferrucci L, Ciol MA, Guralnik JM. Environmental demands associated with community mobility in older adults with and without mobility disabilities. *Phys Ther*. 2002;82(7):670-81.

38. Stansfield BW, Hillman SJ, Hazlewood ME, Robb JE. Regression analysis of gait parameters with speed in normal children walking at self-selected speeds. *Gait Posture*. 2006;23(3):288-94.

39. Sun, R., R. Guerra, and J.B. Shea, *The posterior shift anticipatory postural adjustment in choice reaction step initiation.* Gait & Posture, 2015. **41**(4): p. 894-898.

40. Tromp AM, Pluijm SM, Smit JH, Deeg DJ, Bouter LM, Lips P. Fall-risk screening test: a prospective study on predictors for falls in community-dwelling elderly. *J Clin Epidemiol*. 2001;54(8):837-44.

41. T.S. Keller, A.M. Weisberger, J.L. Ray, S.S. Hasan, R.G. Shiavi, and D.M. Spengler, Relationship between vertical ground reaction force and speed during walking, slow jogging, and running, Clinical Biomechanics 11 (1996) 253.259.

42. Tulchin K, Orendurff M, Adolfsen S, Karol L. The effects of walking speed on multisegment foot kinematics in adults. *J Appl Biomech*. 2009;25(4):377-86.

43. Weerdesteyn V, de Niet M, van Duijnhoven HJ, Geurts AC. Falls in individuals with stroke. *J Rehabil Res Dev*. 2008;45(8):1195-213.

44. Welford, A.T., *Reaction Times*. 1980, London: Academic Press.

45. Wittwer JE, Andrews PT, Webster KE, Menz HB. Timing variability during gait initiation is increased in people with Alzheimer's disease compared to controls. *Dement Geriatr Cogn Disord*. 2008;26(3):277-83.

LIST OF TABLES

Table.1. Means (M) and Standard Deviations (SD) Of Demographics

	Age	Height (cm)	Weight (kg)
M ± SD	21.1 ± 0.6	169.5 ± 8.0	72.0 ± 11.7

Table.2. Means, Subjects, and Standard Deviations *t*-values, and *P*-values of Step Time During SRT and CRT tasks

Groups	Mean (ms)	N	Std. Deviation	*t*	Sig. (2-tailed)

SRT	1207.8	8	73.6	-1.5	0.17
CRT	1234.1	8	67.1		

LEGEND OF FIGURES

Figure1: Lab equipment setting.

Figure2: Example of Multi-targets stepping tasks in Physical Therapy.

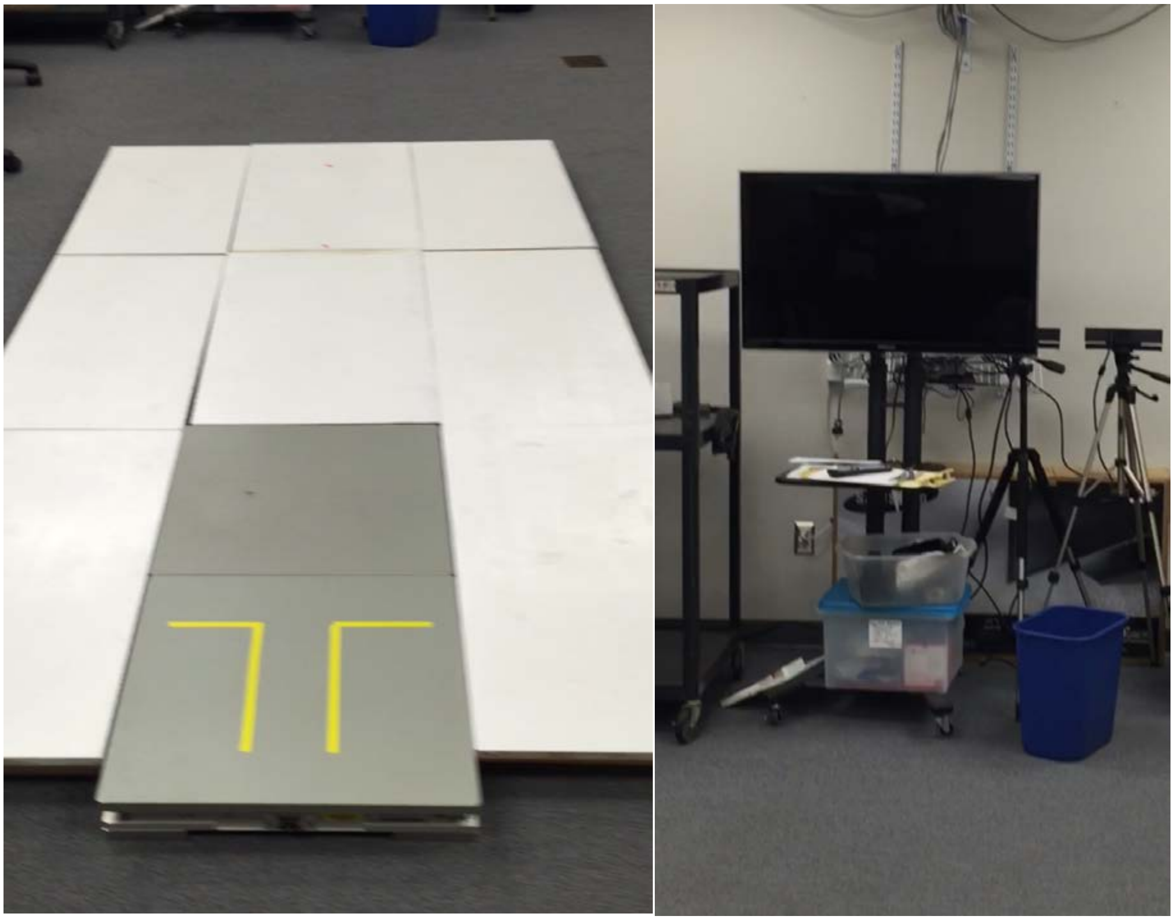

Figure1: Lab equipment setting. A walking platform extended from the force plates (left).

An HD screen for visual display (right).

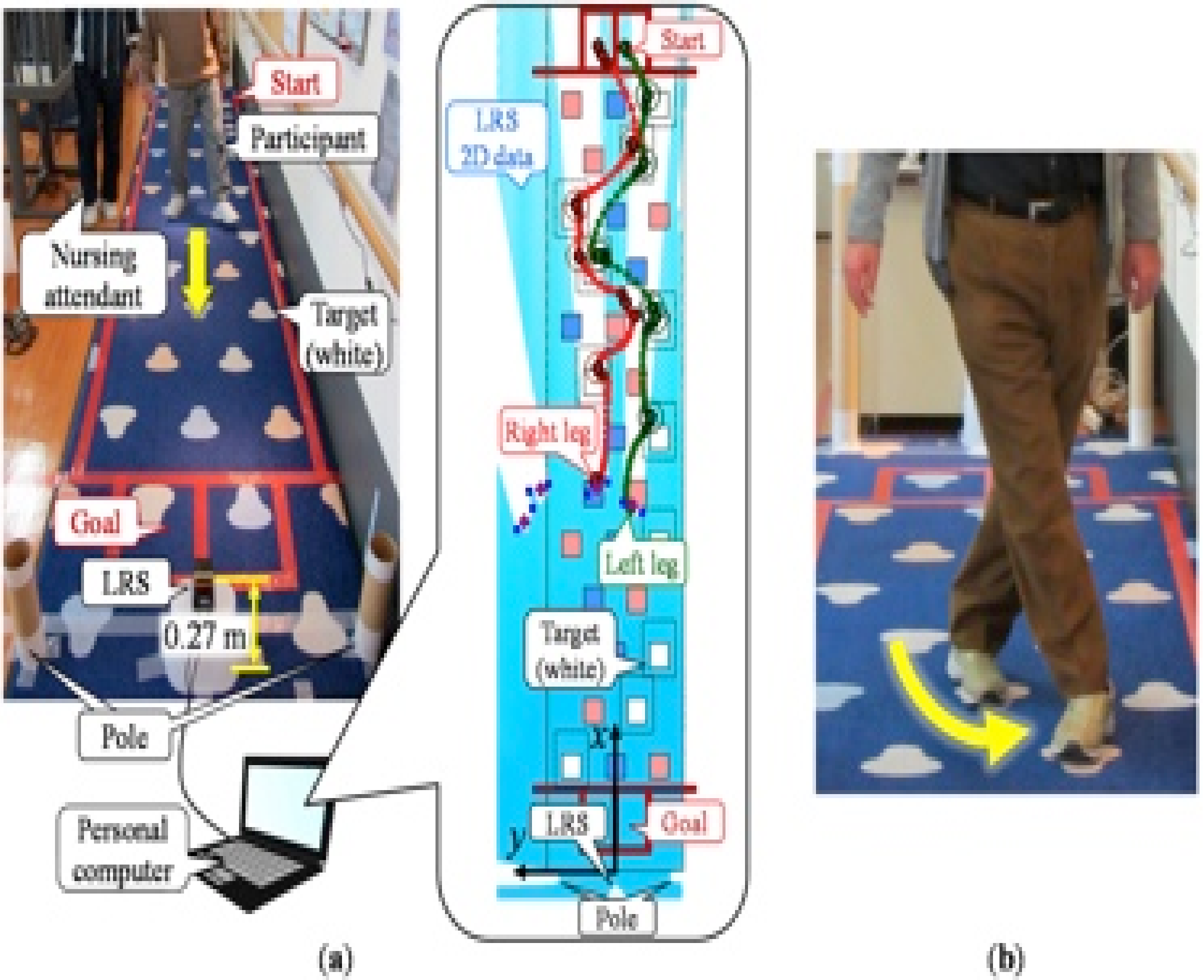

Figure2: An example of specific training program, which has been applied in physical rehabilitation clinics. Multi targets stepping training designed to help patients/elderly with gait problems to minimize risk of falling among elderly and/or those with gait impairment, (Yorozu et al, 2015).

APPENDIX

Appendix-A Consent Form

INDIANA UNIVERSITY INFORMED CONSENT STATEMENT FOR

Response Planning and Execution in Step and Gait Initiation.

You are invited to participate in a research study of the investigation of the time measured from an auditory stimulus to the start of a step. You were selected as a possible subject because of your reply to the recruiting script delivered during one of your classes. We ask that you read this form and ask any questions you may have before agreeing to be in the study.

The study is being conducted by Dr. John Shea in the Department of Kinesiology.

STUDY PURPOSE

The proposed research is designed to comparing the processes underlying the initiation of one step and walk using an auditory stimulus and measuring the time it takes to response and execute among normal healthy young subjects.

NUMBER OF PEOPLE TAKING PART IN THE STUDY

If you agree to participate, you will be one of **10** subjects who will be participating in this research.

PROCEDURES FOR THE STUDY

If you agree to be in the study, you will do the following things:

You will be participating in an investigation of step and gait initiation. Your participation in this investigation will require that you to perform one step or walk (several steps) with a reaction task. Prior to participation, you will be asked for normal vision and any known mental or physical complication impacting vision or memory (e.g. stroke, multiple sclerosis, or paralysis) will be allowed to participate. Additionally, while performing the task, you will be videotaped with a motion analysis system, and the force and pressures underneath your feet and will be measured.
These procedures will be conducted at the Indiana University Neuro-Motor Learning Lab within the Department of Kinesiology. Your participation requires 1 visit to the Neuro-Motor Learning Lab and will require approximately 60 minutes of your time.

RISKS OF TAKING PART IN THE STUDY:

There is a risk of falling.

.

BENEFITS OF TAKING PART IN THE STUDY

You are not expected to benefit from participating in this study.

CONFIDENTIALITY

Efforts will be made to keep your personal information confidential. We cannot guarantee absolute confidentiality. Your personal information may be disclosed if required by law. Your identity will be held in confidence in reports in which the study may be published and all databases storing video tape recordings, motion analysis, survey information, assessment results and study data will be stored with identity confidence and secured with passwords that only the study investigators will have access to. All documentation collected during this study will be destroyed via a paper shredder three years after completion of the investigation.

Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the study investigator and his/her research associates, the Indiana University Institutional Review Board or its designees, and (as allowed by law) state or federal agencies, specifically the Office for Human Research Protections (OHRP), who may need to access your research records.

PAYMENT

You will not be paid for participation in this study.

COMPENSATION FOR INJURY

In the event of physical injury resulting from your participation in this research, necessary medical treatment will be provided to you and billed as part of your medical expenses. Costs not covered by your health care insurer will be your responsibility. Also, it is your responsibility to determine the extent of your health care coverage. There is no program in place for other monetary compensation for such injuries. However, you are not giving up any legal rights or benefits to which you are otherwise entitled. Because you are participating in research which is not conducted at a medical facility, you will be responsible for seeking medical care and for the expenses associated with any care received.

CONTACTS FOR QUESTIONS OR PROBLEMS

For questions about the study or a research-related injury, contact the Co-Investigator researcher Tianyu Zhao at 812-349-8769 or Ruopeng Sun at 718-753-3256, or Principal Investigator Dr. John Shea at 812-856-6045. If you cannot reach the researcher during regular business hours (i.e. 8:00AM-5:00PM), please call the IU Human Subjects Office at (812) 856-4242 or (800) 696-2949. After business hours, please call 812-525-9329.

In the event of an emergency, you may contact Tianyu Zhao at 812-369-0116.

For questions about your rights as a research participant or to discuss problems, complaints or concerns about a research study, or to obtain information, or offer input, contact the IU Human Subjects Office at (812) 856-4242 or (800) 696-2949.

VOLUNTARY NATURE OF STUDY

Taking part in this study is voluntary. You may choose not to take part or may leave the study at any time. Leaving the study will not result in any penalty or loss of benefits to which you are entitled. Your decision whether or not to participate in this study will not affect your current or future relations with Indiana University.

SUBJECT'S CONSENT

In consideration of all of the above, I give my consent to participate in this research study. I have the option to withdraw from this study at any time I choose without penalty.

I will be given a copy of this informed consent document to keep for my records. I agree to take part in this study.

Subject's Printed Name:____

Subject's Signature:____**Date**: ____ (Must be dated by the subject)

Printed Name of Person Obtaining Consent:__________________________

Signature of Person Obtaining Consent:____**Date**: ____

Appendix-B Subject Health Form

MEDICAL HISTORY	Yes / No	Unknown	If Yes, Explain	Current / Resolved
1. Head, Eye, Ear, Nose, Throat	☐ Yes ☐ No	☐		☐ Current ☐ Resolved
2. Respiratory	☐ Yes ☐ No	☐		☐ Current ☐ Resolved
3. Cardiovascular	☐ Yes ☐ No	☐		☐ Current ☐ Resolved
4. Gastrointestinal	☐ Yes ☐ No	☐		☐ Current ☐ Resolved
5. Genitourinary	☐ Yes ☐ No	☐		☐ Current ☐ Resolved
6. Musculoskeletal	☐ Yes ☐ No	☐		☐ Current ☐ Resolved
7. Neurological	☐ Yes ☐ No	☐		☐ Current ☐ Resolved
8. Endocrine-Metabolic	☐ Yes ☐ No	☐		☐ Current ☐ Resolved
9. Blood/Lymphatic	☐ Yes ☐ No	☐		☐ Current ☐ Resolved
10. Dermatologic	☐ Yes ☐ No	☐		☐ Current ☐ Resolved
11. Psychiatric	☐ Yes ☐ No	☐		☐ Current ☐ Resolved
12. Allergy	☐ Yes ☐ No	☐		☐ Current ☐ Resolved
13. Other, specify: ____________	☐ Yes ☐ No	☐		☐ Current ☐ Resolved

Appendix-C Data Collection Form

Gait Study Test Sheet

Subject ID: ___________ Date of Testing: __________

Age: ________________ Male Female

Height: ______________ Weight: ________________

Test Order	Experiment Condition	Practice Trail		Trails Collected		Notes
1	SRT L	1		1		
		2		2		
		3		3		
		4		4		
		5		5		
		6		6		
		7		7		
		8		8		
		9		9		
		10		10		
2	SRT RL	1		1		
		2		2		
		3		3		
		4		4		
		5		5		
		6		6		
		7		7		
		8		8		
		9		9		
		10		10		
3	SRT LRL	1		1		
		2		2		
		3		3		
		4		4		
		5		5		

		6		6		
		7		7		
		8		8		
		9		9		
		10		10		
4	SRT R	1		1		
		2		2		
		3		3		
		4		4		
		5		5		
		6		6		
		7		7		
		8		8		
		9		9		
		10		10		
5	SRT LR	1		1		
		2		2		
		3		3		
		4		4		
		5		5		
		6		6		
		7		7		
		8		8		
		9		9		
		10		10		
6	SRT RLR	1		1		
		2		2		
		3		3		
		4		4		
		5		5		
		6		6		
		7		7		
		8		8		
		9		9		
		10		10		
7	CRT	1		1		
		2		2		
		3		3		
		4		4		
		5		5		
		6		6		
		7		7		
		8		8		
		9		9		
		10		10		
				11		
				12		
				13		

				14		
				15		
				16		
				17		
				18		
				19		
				20		
				21		
				22		
				23		
				24		
				25		
				26		
				27		
				28		
				29		
				30		
				31		
				32		
				33		
				34		
				35		
				36		
				37		
				38		
				39		
				40		
				41		
				42		
				43		
				44		
				45		
				46		
				47		
				48		
				49		
				50		
				51		
				52		
				53		
				54		
				55		
				56		
				57		
				58		
				59		
				60		